

GEOMORPHOLOGY OF THE KAIKOURA AREA

SATISH CHANDRA*

Department of Geography, University of Canterbury

Abstract

The major physiographic units in the Kaikoura area are the Peninsula Block, Beach Ridges and Raised Beaches, Hard Rock Areas and the Alluvial Fans. Erosion of the Seaward Kaikoura Mountains and the transfer of the debris to the sea by fan streams have contributed to coastline progradation so that a former offshore island, now called the Kaikoura Peninsula, has been joined to the mainland. On the piedmont alluvial plain between the mountains and the sea Otiran Glacial Stage and Holocene fan deposits have covered up older fan surfaces. Stillstands during the tectonic uplift of the Peninsula Block when marine processes cut shore platforms and also higher stands of interglacial sea levels in the Late Pleistocene have contributed to the development of erosion surfaces. Along the coast beach ridges and raised beaches have developed during post-glacial times.

INTRODUCTION

The Kaikoura area, as defined for this paper, comprises 64 square miles of low-lying land on the northeast coast of the South Island, New Zealand (Figure 1). The boundaries which have been recognised for this survey are Hapuku River in the north, including the lower Puhi Puhi Stream; Kahutara River in the south, with its Cribb Creek tributary; the eastern slopes of the Seaward Kaikoura Mountains on the northwest, up to about 1,000 feet and including the lower gorges of the streams; and in the east is the sea coast. The area, centred on Kaikoura and fringed by high greywacke mountains on three sides, forms an integrated geomorphological unit in which it has been possible to distinguish four major physiographic units on which a relative chronology of landform development could be based.

The basement rocks are the Jurassic-Lower Cretaceous greywackes of the Torlesse Group (Figure 2). The Tertiary cover on the Kaikoura Peninsula, lying on Mata Series sandstone of Upper Cretaceous age is overlain by Paleocene Amuri limestone which in turn is overlain by Oligocene grey marls (McKay, 1886; Lensen, 1962).

The general structural trend of the basement rocks and the Tertiary cover on the Kaikoura Peninsula is northeast — southwest. McKay (1891) considered Mt Fyffe Ridge, a seaward facing spur of the Seaward Kaikoura Mountains, to be an overthrust along the NE - SW striking Kaikoura Fault with its fault plane dipping steeply to the west. The upthrown block on the northwestern side of the Kaikoura Fault consists of old rock cores of fault-broken over-turned anticlines and the southeastern down dropped block is a synclinal fault-angle depression (Cotton, 1950). On the Kaikoura Peninsula a slightly asymmetrical anticline is flanked on either side by two synclines which have axial planes parallel to the Kaikoura Fault.

* Now at Soils Section, Department of Agriculture, Suva, Fiji

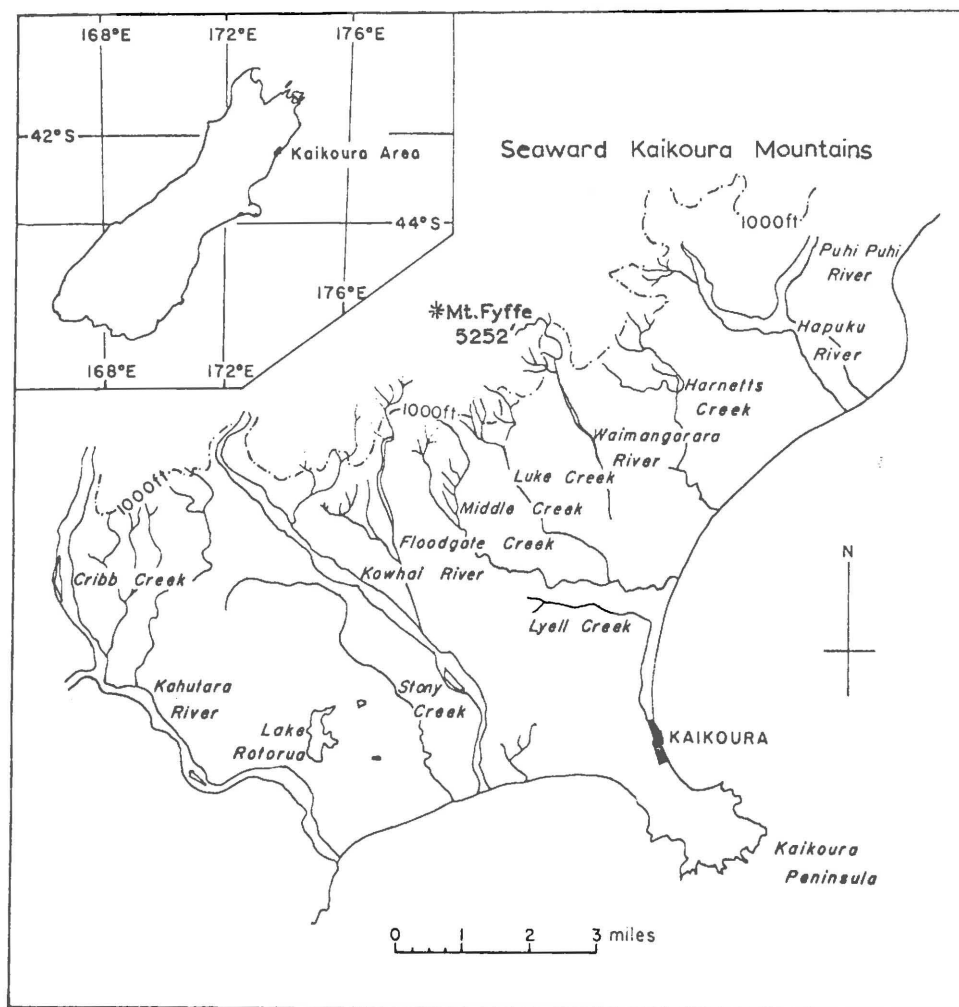


Figure 1 Location of the study area. The main physical features are indicated.

The four major physiographic units in the Kaikoura area are: 1. Peninsula Block, 2. Beach Ridges and Raised Beaches, 3. Hard Rock Areas and 4. Alluvial Fans.

The main criteria used for the recognition of landform chronology are: degree of weathering of deposits, especially of the matrix (Suggate, 1965); degrees of dissection and/or modification of land surfaces; extent and intensity of soil profile development; topographic continuity and relative heights of depositional surfaces, interpolated from 150 Marlborough Catchment Board bench marks; stratigraphic relationships and overall lithologic identity. Because there was a variation in the usefulness of different criteria, (this being very easily apparent during fieldwork) it was found that all available criteria had to be used and that it was not possible to depend solely on a particular one.

This report which is a part of a recent investigation (Chandra, 1968), deals with the geomorphology and chronology of development of the four physiographic units in the Kaikoura area.

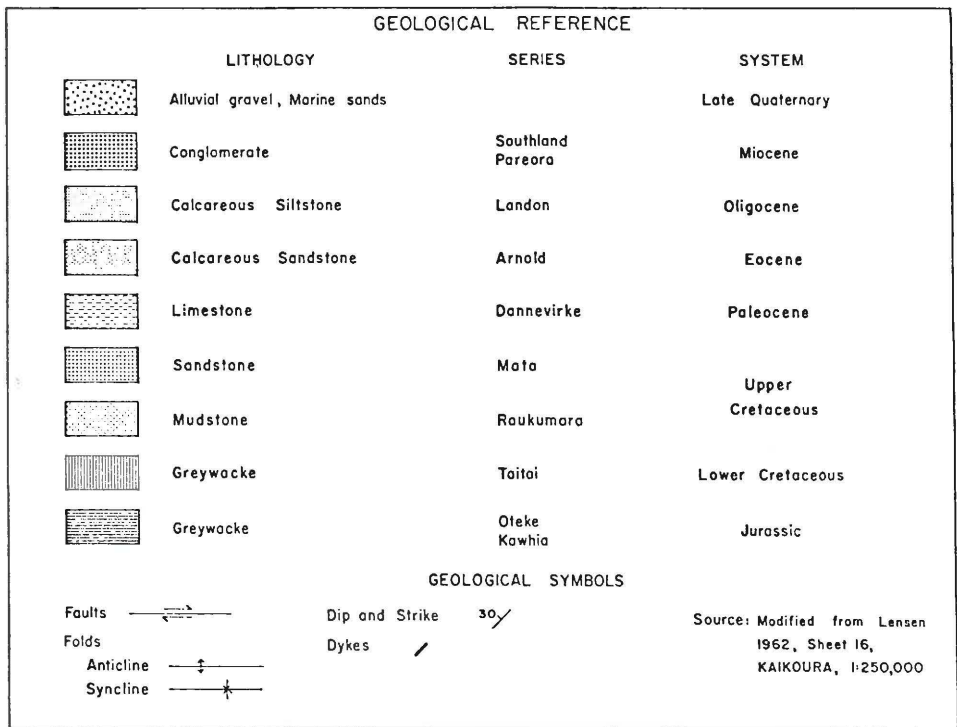
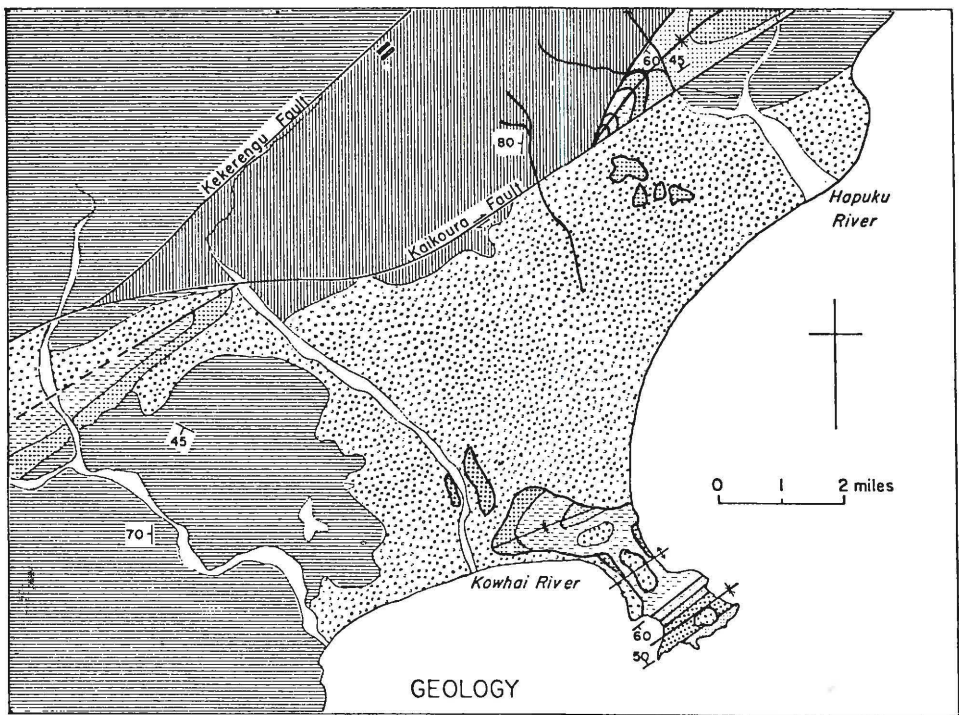


Figure 2. Geology of the Kaikoura area.

PENINSULA BLOCK

The Peninsula Block comprises the Kaikoura Peninsula and the associated hill area to the west, including the Lower Kowhai Hills (Figure 3).

Erosion Surfaces

That there are erosion surfaces on the Kaikoura Peninsula, has long been recognised (McKay, 1886; Cotton, 1914, 1916; Morgan, 1916; Henderson, 1924; Jobberns, 1928; Suggate, 1965) and it has been postulated that the surfaces mark

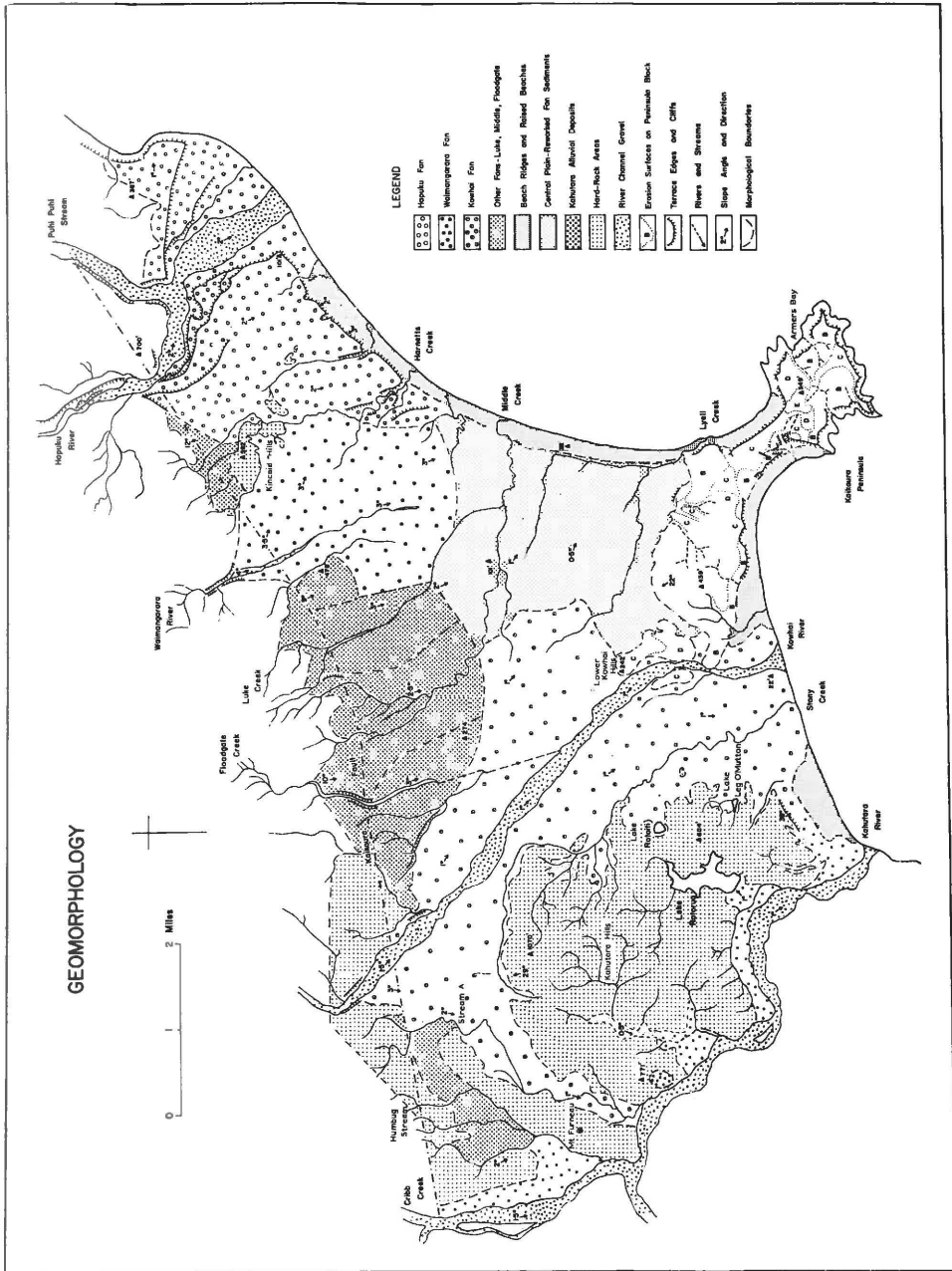


Figure 3. Geomorphology of the Kaikoura area.

former shore platforms, and to explain their present high-level position rapid Quaternary uplift has been suggested. Suggate (1965) considered a net uplift in the order of +350 feet and recognised four erosion surfaces with an estimated height range of 358 feet — 320 feet; 270 feet — 240 feet; 200 feet — 170 feet, and about 120 feet respectively above present day sea level. For ease of reference these would be referred to as E, D, C and B erosion surfaces respectively. These surfaces have been tentatively mapped as subsequent modification of the initial form by erosion and slope wash (this being partly related to lithology and structure) has altered much of the surface character, so that it has become impossible to locate the exact boundaries. Such modification has been greater on the western hills than on the Peninsula proper.

On the Kaikoura Peninsula, both C and B erosion surfaces have well sorted, rounded, fine marine gravels below the soil cover. The deposits usually occur in thinly bedded lenses. Suggate (1965) has suggested that the marine deposits on C erosion surface have a probable correlation with Parikawa Formation of Terangian Interglacial Stage.

Structural Control

The northeast - southwest strike of the Tertiary rocks on the Kaikoura Peninsula is reflected in the stream patterns. Apart from the headwaters of the streams, the lower courses are aligned with the general structural trend.

Because of its location exposed to wave energy (McLean, 1967), cliff-recession has been rapid around the Kaikoura Peninsula, leading to the formation of shore platforms. On the shore platforms steeply dipping limestone and grey marl beds show topographic prominence over less indurated arenaceous bands. Marine erosion has also been aided by the presence of numerous small scale faults and joints. The presence of shore platforms and numerous outlying rocks with tops at or above high tide level (Morgan, 1916) and the presence of an 80 - 100 yard wide strand-plain at the head of Armers Bay (Jobberns, 1928) have been interpreted as evidence for indicating comparatively recent uplift of the Peninsula.

Along the limestone cliffs facing the Lyell Creek mouth are some high-level caves, six to eight feet above sea level containing marine worn greywacke pebbles.

BEACH RIDGES AND RAISED BEACHES

Two distinct marine depositional landforms are present on either side of the Kaikoura Peninsula. North of the Peninsula geomorphological criteria suggest the presence of a former barrier spit, and beach ridges occur to the south of the Peninsula.

Northern Barrier Spit

The barrier spit extends for five miles from two miles southwest of Hapuku River mouth, and narrows to Lyell creek in the south. Absolute height along the central ridge as indicated by Marlborough Catchment Board bench marks, varies from 28 feet 6 inches in the north to 26 feet in the south. The average width is 130 - 140 yards. West of the barrier spit, at its southern end, is a low-lying area of impounded drainage where the outward edge of alluvial fans merge with marine deposits. That the deposits are marine is indicated by size, shape and sorting of particles in thinly-bedded lenses, proximity to present beach material and the evenness of surface form.

Southern Beach Ridges

South of the Kaikoura Peninsula beach ridges occur only in two isolated remnants as the central portion of the coast has been eroded by Kowhai River and Stony Creek which have deposited an infilling of alluvium. The section north-

east of Kahutara River mouth has two distinct surfaces with an altitude difference of 3 - 5 feet. Other isolated ridges are also present but these are not prominent over any appreciable area.

HARD ROCK AREAS

The characteristic topographic form on the greywacke is one of deeply dissected landscape. The relatively long exposure of these areas to atmospheric conditions and therefore their greater age as compared with other landform surfaces in adjacent physiographic units, is indicated by the development of fine textured (18 inches to 6 feet deep) soils. Kahutara hill soils (Gibbs and Beggs 1953) have a well developed A horizon of dark brownish-grey silt loam with a weak granular structure. The B horizon consists of pale-yellow, moderately compact, silt loam. Whereas this is true on altitudes less than 1,000 feet, on steep lands of the Seaward Kaikoura Mountains, relatively shallow stony Kaikoura Loams merge with active scree slopes of the mountain tops.

Lake Formation

The three lakes in Kahutara Hills — Lake Rotorua (135 acres), Lake Rotoiti (9.6 acres) and Lake Leg O'Mutton (6.4 acres) are the results of infilling of exits to tributary valleys by the main stream causing blockage of outgoing drainage and formation of the lakes.

Between Lake Rotorua and Kahutara River channel is a poorly defined river terrace, 10 feet to 15 feet high, with a gentle slope towards the lake. Kahutara River channel was at one time lower in elevation than its present position and a small tributary of the Kahutara, draining the eastern hill area, flowed through the valley now occupied by the lake. At some time aggradation of the Kahutara River channel effectively blocked off the entrance to this valley so that its valley floor, which escaped aggradation, became lower in elevation than the main river channel level. It is possible that at this time some of the river waters flowed away from the main stream into this depression. Later in the sequence of events Kahutara River degraded its channel by 10 feet to 15 feet, leaving a ridge of shingle across the valley mouth and effectively damming it. Over the period of years runoff from adjacent catchments collected and produced the present lake.

Lake Rotoiti and Lake Leg O'Mutton originated when Kowhai Fan material dammed junctions of tributary valleys. Those valleys that either have not had such obstructions at their junctions or have not had sufficient runoff within their catchments, are depositional basins containing swamps and marshes.

Former Sea Cliffs

At the southern end of Kahutara Hills area, half a mile inland from the coast, remnants of 40 feet to 50 feet high cliffs, terminate suddenly in the beach ridges discussed previously. The suggestion from this lithological contact and topographic evidence is that these are former sea cliffs.

Kincaid Hills

The Kincaid Hills, consisting of sandstone of Mata Series, protrude through Hapuku and Waimangarara alluvial fans. Large areas of the lower parts of these hills have been covered by material delivered by fan streams issuing from the Seaward Kaikoura Mountains.

Fault-Scarps

The Kaikoura Fault runs through the base of the Seaward Kaikoura Mountains and numerous fault-scarps and scarplets occur along this line of fracture. On the left bank of Floodgate Creek stream tributaries have become captured in such fault-line depressions. Recent small scale horizontal and vertical displacements of two to three feet are not uncommon.

Mount Fyffe Slopes

The main Mount Fyffe Ridge has several peaks rising to over 5,000 feet with Mount Fyffe reaching 5,252 feet. The greywackes and argillites are extremely contorted and complexly folded and thus have a high degree of instability and erodibility when exposed to weathering processes. Saddles, narrow basins, active scree slopes, scarps, tarns, waterfalls and bare rock are present. During winter months snow covers the upper 2,000 feet and during heavy falls the snowline drops to about 2,000 feet above sea level.

ALLUVIAL FANS

Alluvial fans and cones with their lower reaches of reworked fan sediments cover 65 per cent of the study area. Streams have issued at sufficiently small distances from the Seaward Kaikoura Mountains and Mount Fyffe Ridge, to build Kowhai, Floodgate, Middle, Luke, Waimangarara and Hapuka alluvial fans. Commonly, in between such large fans, are alluvial cones which are products of streams of lower discharge. Coalescence of the major fans and cones at their lateral edges has produced a piedmont alluvial plain or bajada (Cotton, 1950), with reworked alluvial sediments on the lower reaches of rivers that are responsible for building up the plain.

On the central plain neither fan nor interfan areas can be easily distinguished and it is only towards the higher reaches of the streams that a series of fans can be seen which are separated by broad, ill-defined, shallow depressions.

Multiple Fan Surfaces

Including the gravel washes in the stream beds, three main fan surfaces can be distinguished at the fan apices of Waimangarara, Floodgate and Kowhai Fans. Twenty feet above the gravel washes are the major surfaces of the piedmont alluvial plain and 40 feet to 50 feet above these are the high-level fan surface

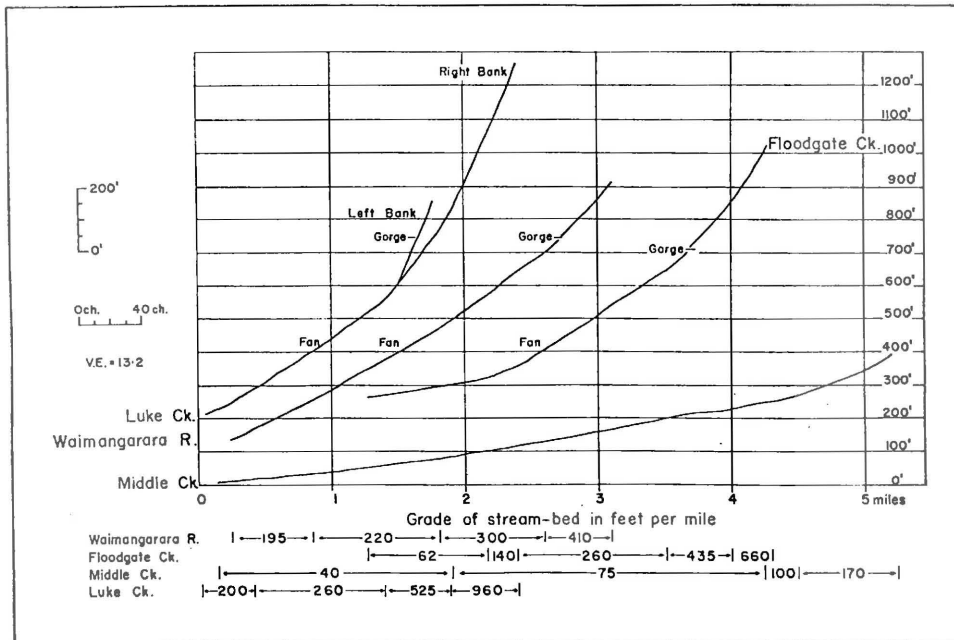


Figure 4. Longitudinal profiles of fan streams. The grade of stream bed is indicated in feet per mile. The curves were plotted from data supplied by the Marlborough Catchment Board.

remnants. The degree of weathering of matrix and cobbles and boulders in these high-level fan remnants is far greater than in the lower and major fan deposits whereas the material in the gravel washes is relatively unweathered. Also the soils on the high-level fans have a more intensively developed A horizon than that which is present on the lower and major fan surface.

The Hapuku Fan has two main paired aggradational terraces on its major fan surface. The difference between them in altitude is about 40 feet. As compared with the lower terrace the upper terrace has a more modified topography, weathering of the matrix is more intensive and there is greater soil development. However the degree of weathering, topographic modification, and soil development is far less than that on the high-level fan deposits and even less than on the Hard Rock areas discussed previously.

Fan Stream Gradients

Although all fan streams have steep longitudinal profiles, some have steeper gradients in their upper reaches (Figure 4). Luke Creek Fan with its two tributaries and Floodgate Creek Fan in their upper reaches have much steeper gradients than Middle Creek and lower Floodgate Creek fans. These gradients are exceptionally steep even by New Zealand standards. Hapuku River has a gradient of 120 feet per mile (or 1 : 44) for the first mile from its mouth. At the gorge mouth, six miles from the coast, the Kowhai River bed is 600 feet above sea level, giving an average gradient of 100 feet per mile (or 1 : 52.8).

RELATIVE CHRONOLOGY OF LANDFORM DEVELOPMENT

Pre-Late Pleistocene Developments

During the cataclysmic Plio-Pleistocene Kaikoura Diastrophism (Kingma 1959) the Seaward Kaikoura Mountain fault block which is separated by large dextral transcurrent fault zones on the northeast coast of South Island (Wellman, 1956), emerged to be eroded into its present shape (Figure 5).

It is difficult to assess when the uplift of McKay's (1886) "limestone island" (now the Kaikoura Peninsula) started but it is not improbable, as there is no evidence to the contrary, that uplift was related to the general effects of Kaikoura Diastrophism and the folding of sandstone, limestone and grey marls strata could be a result of such tectonic stresses. Uplift of the island occurred, though not continuously, throughout the Late Pleistocene and may have extended even into the Holocene.

Continuous erosion of the Seaward Kaikoura Mountains and the foothills produced an ever changing landscape. Kincaid Hills and the Kahutara Hills area are remnants of former and much larger topographic features. The agents of erosion delivered material into a large bay formed between Kahutara Hills, the Seaward Kaikoura Mountains and the Puhi Puhi greywacke promontory. At this time Kincaid Hills would have been a peninsula jutting out into this bay from the main mountain range. The "limestone island" was located several miles offshore and the seas in between the island and the mainland could not have been of any considerable depth as rapid progradation of the coastline occurred in the form of delta-fan building once rivers began to discharge into the bay.

Late Pleistocene Developments

The fan-building process continued into the Late Pleistocene and Holocene. It is possible that during the Porikan, Waimaungan and Waimean Glacial Stages as in the Otiran Glacial Stage (Figure 6), the accelerated mechanical erosion on mountains over 5,000 feet (and probably much higher previously), within four to five miles of the coast, produced greater amounts of debris on the fans than during the associated interglacials. Devegetation of the mountain tops

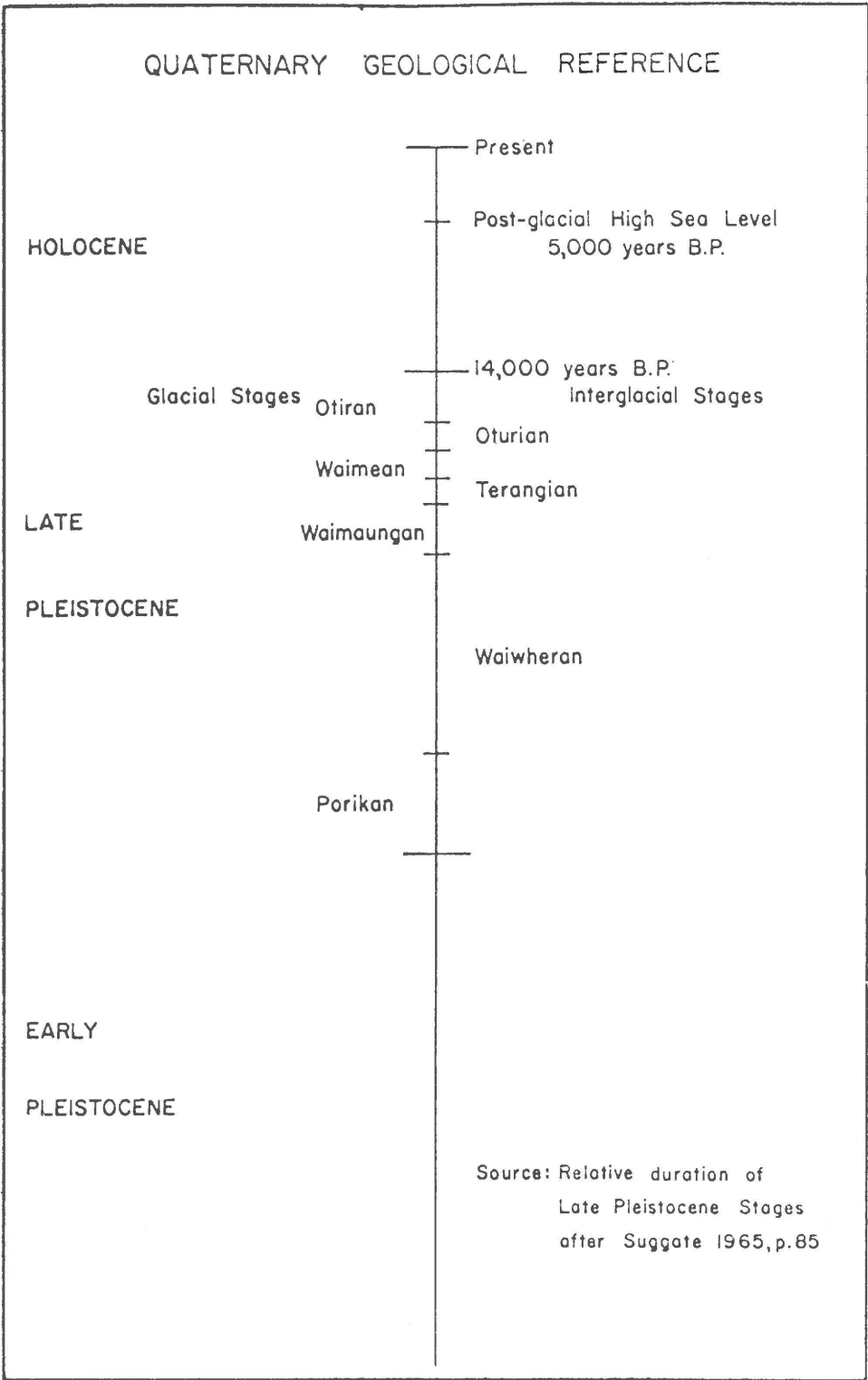


Figure 6. Quaternary Geological Reference.

that accompanied increased cooling, also contributed to the overloading of rivers during glacial periods.

During the Glacial periods the coastline prograded relatively fast and it was during the later stages of the Late Pleistocene that the confluent delta-fans joined the "limestone island" to the mainland and thus formed the Kaikoura Peninsula. When the delta-fan of the Kowhai River abutted against the hills of the Kaikoura Peninsula, it is probable that this river discharged both north and south of the Peninsula from time to time. However at some later date the Kowhai River was arrested between the Kahutara Hills, and the Kaikoura Peninsula, so that progradation of the coastline is still continuing in this area.

During the Waiheran, Terangian and Oturian interglacial stages when the discharge of material may have been lower than during the glacials, fan streams such as the Kowhai, Floodgate, Waimangarara and Hapuku Rivers would have lowered their gradients from those attained for the transportation of excessive loads during the glacials. If degradation of fan surfaces can be associated with the interglacials and aggradation associated with the glacials, then the only probable localities for the occurrence of pre-Otiran fan deposits would be on altitudes higher than the Otiran fan surfaces. The highly weathered high-level fan deposits at the mouths of the gorges of Waimangarara, Floodgate and Kowhai Fans represent such pre-Otiran fan deposits but it is not yet clear to which previous glacial stage they belong (Figure 7).

With the onset of the Otiran Glacial Stage accelerated mechanical erosion of the Seaward Kaikoura Mountains was again initiated, and large areas of the piedmont alluvial plain were formed during this time. Fan surfaces formed during earlier glaciations and areas adjacent to Kincaid Hills were covered by Otiran fan deposits that have been well preserved, as no significant geomorphic change has taken place subsequently. In the north, Hapuku Fan, depositing large amounts

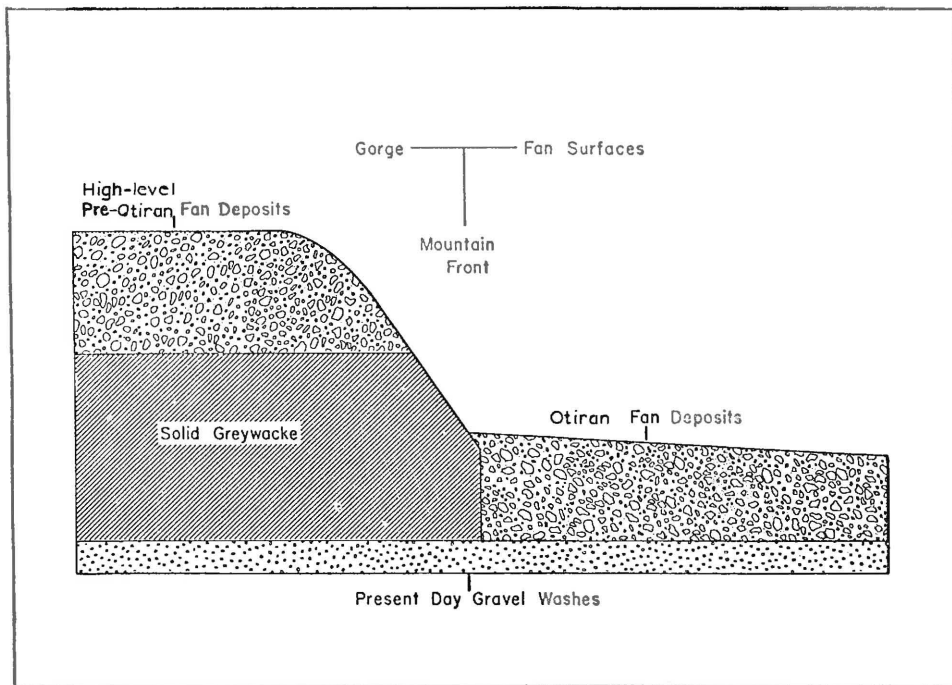


Figure 7. Generalised profile of multiple fan surfaces at the Waimangarara gorge.

of debris in the sea, produced a rapidly prograding delta-fan. Cutting of the lower matched terraces of the Hapuku Fan (these terraces are less weathered, less modified and having a shallower soil cover than the upper terraces) occurred during the late Otiran Stage when the peak of fan sedimentation had passed and degradation of the fan started.

Previous authors working in the Kaikoura area, such as Cotton (1914, 1916), Morgan (1916), Jobberns (1928) and Suggate (1965), ascribed the origin of erosion surfaces on the Kaikoura Peninsula to periods of stillstands during the tectonic uplift when the sea effectively cut shore platforms at different levels. The present attempt to explain the origin of these erosion surfaces takes into account the effects of the two variables that have most likely affected this low-lying area during the Late Pleistocene. These are tectonic changes and eustatic sea level fluctuations.

Since the extreme limits of sea level fluctuations between the Eem interglacial and Würm Glaciation in Europe is given as +98 feet and —290 feet to —325 feet (Flint 1957) and it has been suggested by Suggate (1965) that correlations can be made with the Oturian Interglacial and Otiran Glaciation of New Zealand, it is reasonable to suggest, as noted by Cotton (1914, 1916) and Jobberns (1928), that some uplift of the Kaikoura Peninsula has taken place subsequent to the formation of E and D marine terraces now standing at 358 feet to 320 feet and 270 feet to 240 feet above sea level respectively.

Earlier in this report it was mentioned that both C (200 feet to 170 feet) and B (120 feet) erosion surfaces on the Kaikoura Peninsula have well sorted, rounded, fine marine gravels below the soil cover and that Suggate (1965) suggested that marine deposits on the C erosion surface have a probable correlation with Parikawa Formation of the Terangian Interglacial Stage. Assuming this to be reasonable, it is suggested that the marine deposits on the B erosion surface are correlatives of the Winterholme Formation of the later Oturian Interglacial Stage (Figure 8). Some uplift of the Kaikoura Peninsula has taken place after the Terangian Interglacial sea eroded the C erosion surface and deposited beach material on it. Later on in the sequence of events the Oturian Interglacial sea eroded another marine platform, lower than the previous one, and also deposited beach material on its surface. The marine deposits on the B erosion surface are several feet thick only and this can be explained because littoral deposits for any single position of sea level, especially on shore platforms, cannot attain a great thickness as the deposition is limited by the tidal range.

Late Pleistocene strike-slip and dip-slip fault movements on the Kaikoura Fault are recorded by numerous relatively unmodified fault-scarps and smaller scarplets. Movement in post-Otiran times is suggested by a small scale displacement of the Otiran fan surface at the mouth of Waimangarara gorge. However a fault-scarp extending for four miles from Kowhai gorge to Luke Creek, noted by Wellman (1953), is assumed to have formed prior to the Otira glaciation as no significant displacement is shown on the Otiran fan surface.

Holocene Developments

Fan building and destruction of some areas of Otiran fan surfaces have continued throughout the Holocene, as is indicated by the geomorphic changes that occur during the catastrophic floods of 20 - 50 year periodicity (Thomson and MacArthur, 1968). Large areas of Otiran fan surface on the Kowhai Fan have been covered by Holocene sediments.

South of the Kowhai gorge, between Mt Furneau and Kahutara Hills area, is a valley at present being drained by Stream A which flows into the Kahutara River. At its fan apex the elevation of the Kowhai River bed is much greater than the elevation of the valley floor of Stream A and it appears that in the not-too-distant past the Kowhai River flowed into Kahutara River. At a later

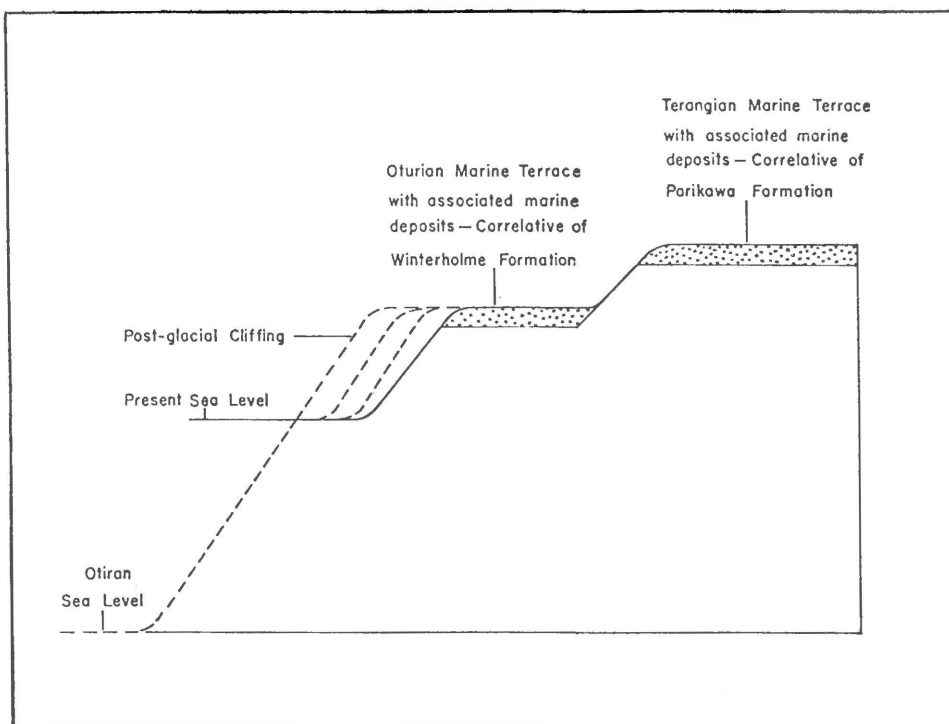


Figure 8. Generalised profile of the origin of Oturian marine terrace (120 feet erosion surface). The associated marine deposits are a likely correlative of Winterholme Formation.

date in the Holocene the Kowhai River regained its former southeast direction of flow.

The mode of origin of Lake Rotorua, Lake Rotoiti and Lake Leg O'Mutton has been discussed previously. Since the fan materials attain great thicknesses on the piedmont alluvial plain it is reasonable to expect that damming of the lakes would have started in the Late Pleistocene and culminated during the Holocene.

Whereas it is appreciated that opinions on a higher stand of post-glacial sea level are divergent (Jelgersma, 1966; McFarlan, 1961; Curray, 1961; Godwin, Suggate and Willis 1958; Fisk, 1951; Shepard 1964; Shepard and Suess, 1957) the postulation of a 10 feet high stand of post-glacial sea level (Fairbridge, 1961; Schofield, 1960, 1964), 5,000 years B.P., in the Kaikoura area provides an explanation for the occurrence of coastal cliffs along the Hapuku Fan, the origin of the northern barrier spit and southern beach ridges, and also accounts for the presence of high-level caves along the coastal cliffs of the Kaikoura Peninsula.

The onset of post-glacial cliffling of the Hapuku Fan was caused by the destruction of the equilibrium existing between Hapuku delta-fan edge progradation and the removal of beach material by shore processes and, with rising sea level combined with less discharge of material from the Seaward Kaikoura Mountains, erosion on the coast surpassed progradation and the general effect on the delta-fan edge has been one of a retrograding coastline. Material delivered to the beach had a net longshore transportation southwards, leading to the formation of a barrier spit which enclosed an arm of the sea in the region of lower Lyell Creek. At this time the waters of Lyell Creek, Luke Creek and

Middle Creek flowed into the estuary which was effectively blocked off on the seaward side by the barrier spit which had an opening somewhere in the vicinity of the present Lyell Creek mouth.

South of the Kaikoura Peninsula post-glacial marine aggradation deposits are backed by post-glacial cliffs cut during the higher stand of post-glacial sea level. At that time the sea washed against the southern end of Kahutara Hills area and also along the cliffs east of the Kowhai River mouth. As the high post-glacial sea level began to drop towards the present level, continuous discharge of material from the Kowhai River caused another spurt of coastline progradation, between the promontories of Kahutara Hills area and the Kaikoura Peninsula. The maximum coastal progradation in the last 5,000 years has been in the order of 400 yards.

The sea caves which are six to eight feet above the present sea level and located along the limestone cliffs facing the Lyell Creek mouth on the northern side of the Kaikoura Peninsula are the result of this higher stand of post-glacial sea level. The infilling of marine worn greywacke pebbles occurred during this time.

The most recent event in the relative chronology of landform development has been the cutting of shore platforms around the Kaikoura Peninsula. Although sea level was higher 5000 years ago the rate of cliff recession has been sufficiently rapid to erode away any previously formed high bench levels.

Some of the shore platforms on the seaward side of the Peninsula are related to the present tidal range and since littoral deposits are lacking on their surfaces, it would appear that the platform surfaces are still being effectively eroded, thus showing the surface form to be considerably younger than 5,000 years.

CONCLUSIONS

The four major physiographic units in the Kaikoura area are the Peninsula Block, Beach Ridges and Raised Beaches, Hard Rock Areas and Alluvial Fans. Geomorphological criteria gathered from these units have enabled the reconstruction of a relative chronology of landform development.

Four levels of erosion surfaces have been recognised on the Peninsula Block. Both tectonic uplift and eustatic sea level fluctuations in the Late Pleistocene have helped account for the origin of these erosion surfaces. It has been suggested that the marine gravels on the 120 feet (B) erosion surface are correlatives of the Winterholme Formation of Oturian Interglacial Stage. Post-glacial cliffing around the Kaikoura Peninsula has destroyed former and wider areas of erosion surfaces leaving behind extensive stretches of shore platforms. Most of the stream courses on the Peninsula Block are controlled by structure.

Development of erosional topography has been prominent on the Hard Rock Areas since their exposure in the pre-Late Pleistocene. Blockage of former valley mouths by fluvial aggradation has led to the development of Lake Rotorua, Lake Rotoiti and Lake Leg O'Mutton.

The origin of the piedmont alluvial plain has been in the form of a series of delta-fans prograding outwards from the Seaward Kaikoura Mountains. Extensive areas of Otiran Glacial Stage and Holocene fan deposits cover the surface of this plain.

With the onset of rising sea level after the Otiran Glaciation the former equilibrium between delta-fan edge progradation of the Hapuku Fan and the removal of material by beach processes was altered, giving rise to a retrograding coastline. Material delivered to the beach system had a net longshore transportation southwards leading to the formation of a barrier spit.

South of the Kaikoura Peninsula beach ridges originated on a prograding coastline when the high post-glacial sea level began to drop towards its present level. In the littoral compartment formed by Kahutara Hills area and the Kaikoura Peninsula the supply of fan material from the Kowhai River has caused a rapid progradation of the coastline.

On a regional scale the most significant geomorphic change in terms of dimensions from pre-Late Pleistocene to present day, has been the progradation of the coastline from the Seaward Kaikoura Mountains to its present position.

REFERENCES

- Chandra, S., 1968: Geomorphology of the Kaikoura Area. *Unpublished M.Sc. Thesis, Geography Department, University of Canterbury*; 90 pp.
- Cotton, C. A., 1914: A Preliminary Note on the Uplifted East Coast of Marlborough. *Trans. N.Z. Inst.* 46: 286-294.
- , 1916: Fault Coasts in New Zealand. *Geog. Review* 1(1): 20-47.
- , 1950: Tectonic Scarps and Fault Valleys. *Bull. Geol. Soc. Am.* 61: 717-757.
- Curry, J. R., 1961: Late Quaternary sea-level: a discussion. *Bull. Geol. Soc. Am.* 72: 1707-1712.
- Fairbridge, R. W., (1961): Eustatic Changes in Sea-Level. In Ahrens, L.H. et. al: *Phys. Chem. Earth*, 5. Pergamon Press, London, 99-185.
- Fisk, H. N., 1951: Loess and Quaternary geology of the Lower Mississippi Valley. *J. Geol.* 59(4): 333-56.
- Flint, R. F., 1957: *Glacial and Pleistocene Geology*. Wiley, New York, 553 pp.
- Gibbs, H. S.; Beggs, J. P., 1953: Soils and Agriculture of Awatere, Kaikoura and Part of Marlborough Counties. *N.Z. Soil Bureau Bull.* 9.
- Goodwin, H.; Suggate, R. P.; Willis, E. H., 1958: Radiocarbon Dating of the Eustatic Rise in Ocean-Level. *Nature* 181: 1518-19.
- Henderson, J., 1924: The Post Tertiary History of New Zealand. *Trans. N.Z. Inst.* 55: 580-99.
- Jelgersma, S., 1966: Sea-level changes during the last 10,000 years: in *International Symposium on World Climate from 8,000 to 0 B.C.* pp. 54-69. Royal Meteorological Society, London.
- Jobbarns, G., 1928: The Raised Beaches of the North East Coast of the South Island of New Zealand. *Trans. N.Z. Inst.* 59: 508-70.
- Kingma, J. T., 1959: Tectonic History of New Zealand. *N.Z. J. Geol. Geophys.* 2: 1-55.
- Lensen, G. J., 1962: Sheet 16 Kaikoura (1st ed.). "Geological Map of New Zealand 1: 250,000". Department of Scientific and Industrial Research, Wellington, New Zealand.
- McFarlan, Jr. E., 1961: Radiocarbon dating of Late Quaternary deposits, South Louisiana. *Bull. Geol. Soc. Am.* 72: 129-58.
- McKay, A., 1886: On the Geology of the Eastern Part of Marlborough Provincial District. *N.Z. geol. Surv. Rep. Geol. Explor.* 1885. 17: 27-136.
- , 1891: On the Geology of Marlborough and Southeast Nelson. *N.Z. geol. Surv. Rep. Geol. Explor.* 1890-1. 21: 1-28.
- McLean, J. F., 1967: Objective Description of Shore Platforms on the Northeast Coast of the South Island. *Unpublished M.A. Thesis, Geography Department, University of Canterbury*; 94 pp.
- Morgan, P. G., 1916: Notes on a Visit to Marlborough and North Canterbury, with special Reference to Unconformities post-dating the Amuri Limestone. *10th Ann. Rept. N.Z. Geol. Surv.* 7 (C-2b): 17-29.
- Schofield, J. C., 1960: Sea-level fluctuations during the past four thousand years. *Nature* 185: 836.
- , 1964: Post-glacial sea-levels and isostatic uplift. *N.Z. J. Geol. Geophys.* 7 (2): 359-70.
- Shepard, F. P., 1964: Sea-level changes in the past 6,000 years; possible archaeological significance. *Science* 143: 574-76.
- Shepard, F. P.; Suess, H. E., 1957: Rate of post-glacial rise of sea-level. *Science* 123: 1082-3.
- Suggate, R. P., 1965: Late Pleistocene Geology of the Northern Part of the South Island, New Zealand. *N.Z. geol. Surv. Bull. n.s.* 77. D.S.I.R.
- Thomson, P. A., MacArthur, R. S., 1968: Kaikoura Scheme-Preliminary Report on the Alternatives for Controlling the Mount Fyffe Streams. *Three Unpublished Marlborough Catchment Board Papers.* 45 pp.
- Wellman, H. W., 1953: Data for the Study of Recent and Late Pleistocene Faulting in the South Island of New Zealand. *N.Z. J. Sci. Tech.* B34: 270-88.
- , 1956: Structural Outline of New Zealand. *Department of Scientific and Industrial Research Bull.* 121: 1-36.